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A MAGNIFICENT IMPLEMENTATION OF SRM DRIVE WITH HIGH POWER FACTOR CORRECTION CAPABILITY IN INDUSTRIAL APPLICATION

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ABSTRACT

The interest over SRM is due to its advantages over the induction motor or permanent magnet synchronous motor. These advantages include low cost, super charged performance, equal or effective reliability, magnificent efficiency, frown volume and ease of production and storage. An SRM drive has made a successful entrance into various sectors of industry such as aircrafts, automotive, and household appliances. In this paper, a two-stage power converter based on the diode bridge rectifier (DBR) is aimed to ameliorate the power factor of Switched Reluctance Motor (SRM) drives. DBR stage in the input of the converter of SRM, which removes capacitors of DC link and create the capability of improving power factor of SRM drives interfacing using asymmetrical converter topology. New simple converter topologies for SRM drive is implemented based on a closed loop control scheme. Ultimately closed loop controller (PI controller) for a Three phase 6/4 SRM drive is modeled in Matlab/Simulink and the results are presented.

KEYWORDS: Switched Reluctance Motor Drives, Converter Topology, Power Factor Correction, Asymmetrical Converter

INTRODUCTION

Due to the advantages of high efficiency and high density of power the single-phase switch mode AC-DC converters are being used as front-end rectifiers for various applications. These conventional converters, gets non-sinusoidal input alternating currents which leads to low input power factors and harmonic injections into the lines [1]. Sceintific explorations in quality of power, utility interference has gained much importance due to good regulation in power quality and rigid limits on total harmonic distortion (THD) of current input. A well-defined linearzed model around the steady-state operating point is possessed by AC-DC rectifiers presenting unity power factor as shown in fig.1 which shows the diagram of power factor correction technique which is improved.

The SRM has become an attractive campainger for different applicationof speed drives and is encouraging due to low-cost, high power switching devices and having many advantages , like elementary construction, having no windings or magnets on rotor, negligible mutual coupling, high fault tolerant and robust structure [1]. Due to lacking in operating power factor, ripple in torque which causes undesirable vibration and acoustic noise causes severe problem in switched reluctance motor drive.Torque ripple can be reduced either by motor design or by suitable controlling methods. Distribution system losses would be a cause due to Low power factor. Therefore, improvement of power factor is essential to enhancing their competitiveness [2].

SRM traditional converter comprises of a front-end large filter capacitor and diode bridge rectifier which is responsible for low power factor (LPF), high current harmonics and low efficiency beacuse it draws current which is in

the form of pulses from the alternating current source side.SRM integrated with in a battery-charging circuit is proposed [3], and is a effective for low-cost battery applications, since it gives high reliability and high efficiency with lesser costs of manuacturing [4]. In order to ameliorate the power factor a two-stage power converter based on the diode bridge rectifier (DBR) as an input stage of the asymmetrical converter is proposed.

In order to properly control SRM, the stator excitation needs to be synchronized with the rotor position. Several Sensorless position detection techniques have been developed in the past few decades [5], to replace the expensive and unreliable physical position sensors. SRM drive has the crucial problem of large torque ripples due to lack of continuity in the generated torque. But this can be mitigated to a great extent by phase current overlapping. Therefore, the converters used for SRM drive requires separate control for each phase, so that the torque ripples can be reduced by phase current overlapping. Another reason for torque ripples is that the stator current falls behind the reference current during the commutation of each SRM phase current because of back EMF. This means that during commutation, the phase current reaches zero after the reference current which causes negative torque and more ripples in the torque produced by the motor. Thus, the converter used in the SRM drive must have the quick commutation ability of phase currents, which will reduce torque ripples considerably.

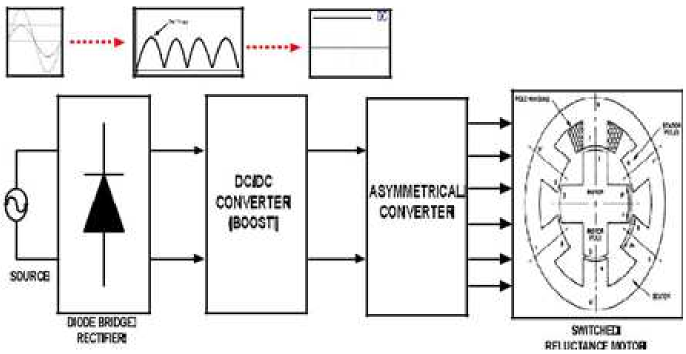

Figure 1: Schematic Diagram of Improved Power Factor Correction Technique

On the other side, there is a winding on the stator and no brushes, no winding on the rotor, as shown in Figure 2. The segments of rotor which establish flux and leads to bend the flux generated by current which is flowing in a in a stator slot coil winding and around that slot and its behind towards the rotor periphery. In add-on to this, the converter circuits will have number of switches which are minimum in number and these are needed due to unidirectional current [6]. The ripple of the torque and noise as a result of this commutation are the other two awkward issues which have to be undertaken. The controlling of SRM becomes a tough task when we encounter the above mentioned issues.

This paper presents novel converter topologies of SRM drive for speed control. To obtain a better transient response, the overall proposed system is implemented in closed loop configuration with PI controller. Proposed two-stage power converter validation through significant reduction of the THD value of the supply current with the line drawn current quality and power factor improvement are evaluated by computer simulations using MATLAB/Simulink platform.

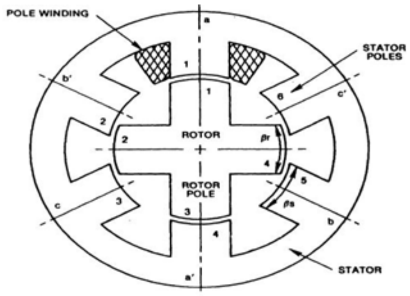

Figure 2: Basic Four Phase 6/4 SRM

Principle Operation of SRM

In the SRM the wound field coils are placed on the stator and no coils or magnets are placed on the rotor. The stator is the stationary part and the rotor is the rotating element which is having poles, they are salient in nature and hence this machine is a doubly salient machine. The stator and the rotor cores are laminated with Ns=2mq poles on the stator and Nr poles on the rotor in the SRM. Assume m be the number of phases and each individual phase is made up of concentrated coils place on poles of a stator designated as 2q. Most preferred configurations amid of multiple options are 6/4 three phase and 8/6 four phase Switched Reluctance Motors's as shown in figure 1. The above configurations is homologous to q = 1 (one pair of stator poles and coils per phase) but q may be equal to 2 or 3 too. Alone one phase switched on, the rotating element rotor will be at rest in a position which provides minimum reluctance for the flux produced by the same phase. In this aligned position, the torque will not be developed in the rotor. Now if the same phase is switched off and the next phase turned on, the torque is experienced by the rotor which tends to move it to a minimum reluctance position corresponding to the new phase [7]. Whichever direction of movement offers the least distance to be moved by the rotor to reach the new minimum reluctance position is the direction of rotor motion. By using the principles of electromechanical energy conversion expressions the singly excited electromagnetic relays have been analyzed and hence the electromagnetic torque was developed. The obtained results can be elongate to the switched reluctance motor and the torque expression is obtained as

$$T_e = \frac{dL(\theta,i)}{d\theta}\frac{i^2}{2} \quad (1)$$

Design of 6/4 SRM Drive

This is acceptable for all SR converter circuits because each main power switching device is always in series with motor winding. Secondly the independence between the phases is high which is more than possible in conventional AC or brushless DC drives. A fault in one of the phase does not affect other phases. Therefore each phase can be operated independently in SR converter circuits [8]. The asymmetric bridge converter is the popular converter among the other converters and the performance of the converter is good. In this asymmetric bridge converter each phase leg consists of two discrete switches and two diodes which are used for continues flow of current when the switches are off, which are shown in Figure 3.

When switches S1 and S2 are switched on, the phase A is activated which is shown in Figure 4. When switches S1 and S2 are switched off, the diodes D1 and D2 are forward biased. In this case phase A is de-activated, which is shown in Figure 5.

For getting a fast transient response, the complete drive system is carried out in closed fashion and the same control principle is used for this 6/4 SRM drive, which is shown in the Figure 6. It represents the overall control scheme with proposed SRM drive topology.

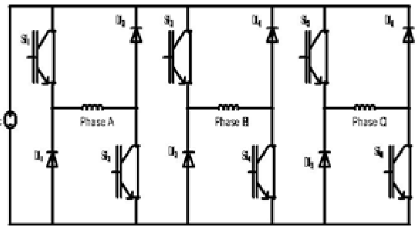

Figure 3: Asymmetrical Bridge Converter for Three Phase 6/4 Pole SRM

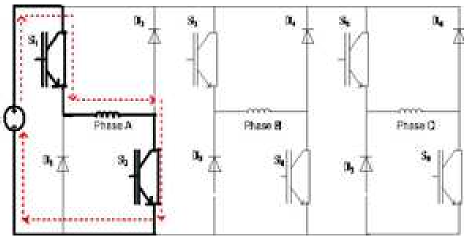

Figure 4: Current Path When PhaseA is Activated

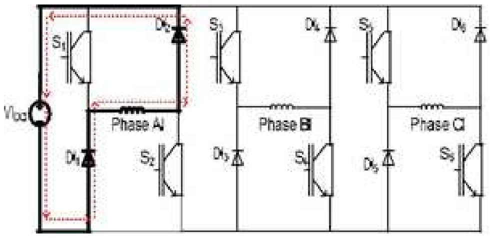

Figure 5: Current Path when Phase a is Deactivated

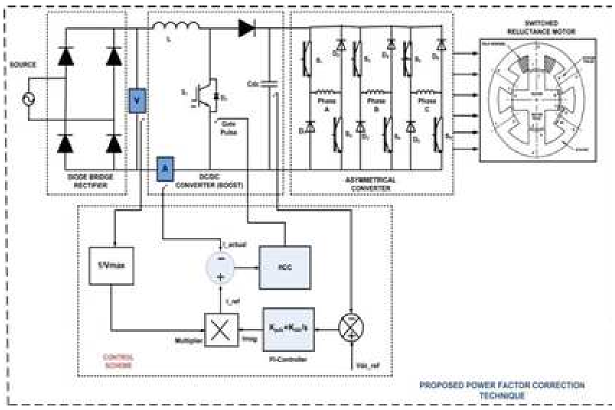

Figure 6: Closed Loop Control Of SRM Drive System

The above figure shows the closed loop control implementation of the SRM drive system, adopted control scheme. Vdc_ref is the reference voltage that is expected at the output of the boost converter & Vdc_actual is the actual output of the boost converter [9]. The error in the output voltage is given to the voltage controller. The voltage controller (PI controller) processes the error signal and produces an appropriate current signal (Imag). The current signal (Iactaul) is multiplied with a unit sinusoidal template which is produced by using a phase locked loop (PLL). The load current I_ref subtracted from the I_actual to produce the reference current signal. As the boost inductor current cannot be a alternating,

the absolute circuit gives the absolute value of the reference current signals given to the current controller to produce the proper triggering signal and the hysteresis current controller is adopted [10].Upper and lower hysteresis band is created by adding and subtracting a band 'h' with the reference signal which generates the required gate pulses for driving dc voltage as a constant and improve power factor at source terminals.

MATLAB/SIMULINK MODELLING AND SIMULATION RESULTS

Here simulation is carried out in divergent cases, in that

AC/DC Conversion without & with DC Link Capacitor.2) AC/DC Conversion with DC/DC Converter 3) Proposed Open Loop & Closed Loop Control of 6/4 SRM Drive.4) Proposed Closed Loop Control of SRM Drive Applications to Power Factor Correction Technique.

Case 1: AC/DC Conversion without & with DC Link Capacitor

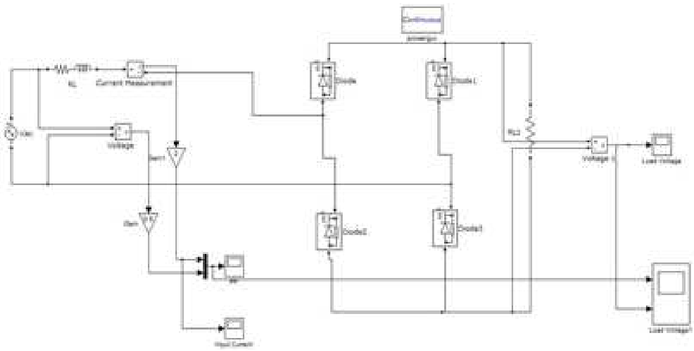

Figure 7: Matlab/Simulink Model of AC/DC Conversion with & without DC Link Capacitor

Figure 7 shows the Matlab/Simulink Model of AC/DC conversion with & without DC Link Capacitor using Matlab/Simulink.

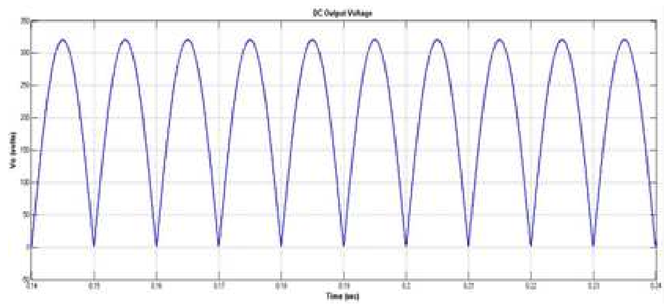

Figure 8: Load Voltage by Proposed AC/DC Conversion without Load Side Filter

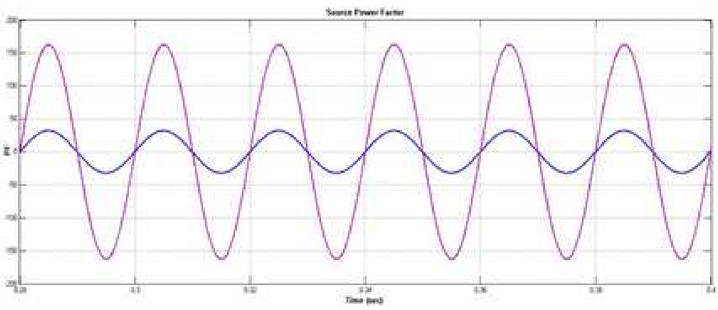

Figure 9: Ure Source Power Factor of AC/DC Conversion without Load Side Filter

Figure 9 Source Power Factor of AC/DC conversion without Load Side Filter, no need of any load side filter never gets constant DC output voltage as well, no distortions present in source side then both source voltages & current will be in in-phase condition.

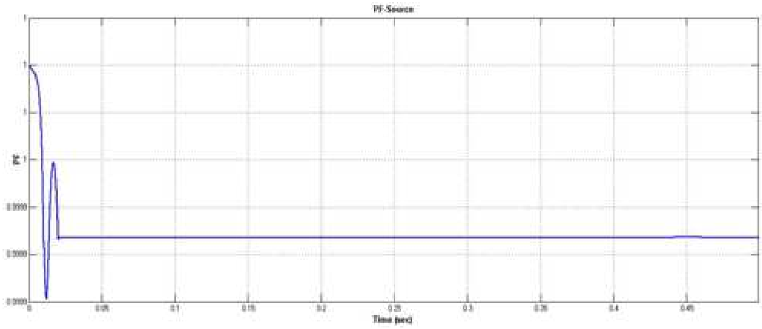

Figure 10: Source Power Factor of AC/DC Conversion without Load Side Filter

Figure 10 Source Power Factor of AC/DC conversion without Load Side Filter, power factor maintained as a 0.99 lag condition.

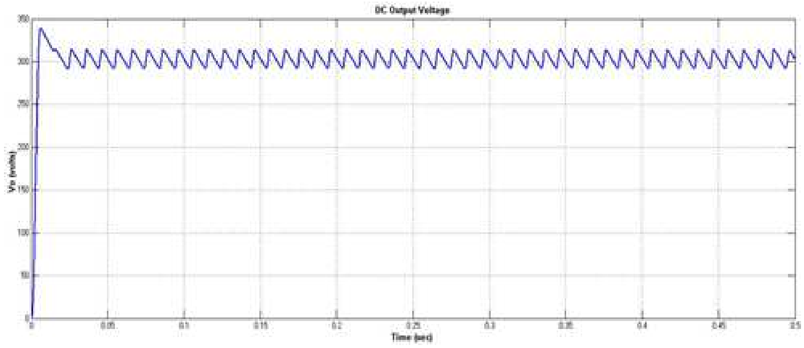

Figure 11: Load Voltage of Proposed AC/DC Conversion with Load Side Filter

Figure 11 shows the Load Voltage of Proposed AC/DC conversion with Load Side Filter, here get constant DC.

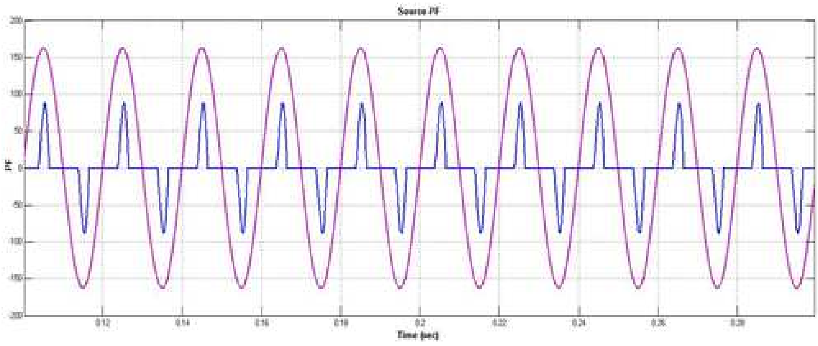

Figure 12: Source Power Factor of AC/DC Conversion with Load Side Filter

Figure 12 Source Power Factor of AC/DC conversion with Load Side Filter, need of load side filter to get constant DC output voltage as well distortions present in source side parameters then both source voltage & current will be in out of -phase condition.

Figure 13 Source Power Factor of AC/DC conversion with Load Side Filter, power factor never maintained as a constant and drop to 0.6 lag condition.

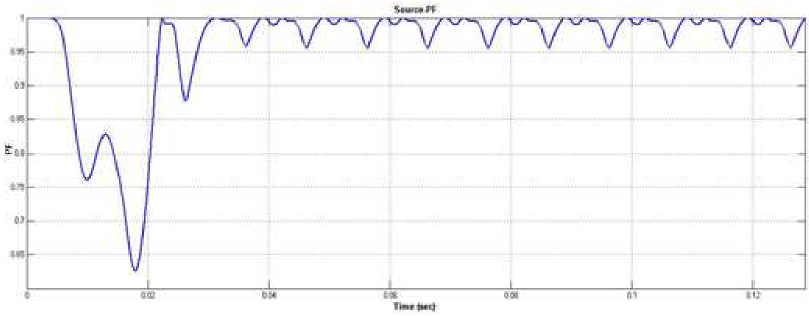

Figure 13: Source Power Factor of AC/DC Conversion with Load Side Filter

Case 2: AC/DC Conversion with DC/DC Converter

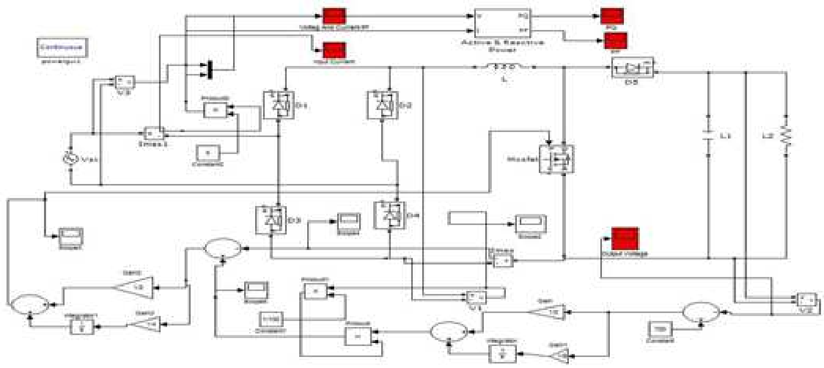

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Figure 14: Matlab/Simulink Model of AC/DC conversion with DC/DC Converter

Figure 14 shows the Matlab/Simulink Model of AC/DC conversion with DC/DC Converter using Matlab/Simulink Platform.

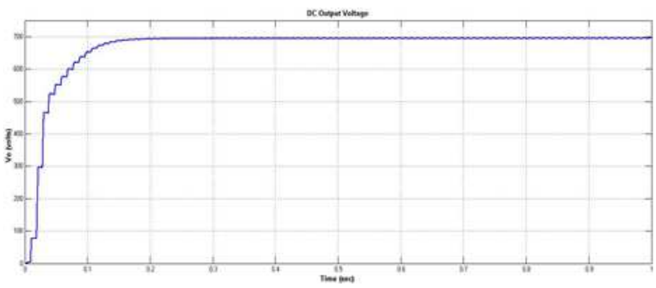


Figure 15: Load Voltage of Proposed AC/D Conversion with DC/DC Converter

Figure 15 shows the Load Voltage of Proposed AC/DC conversion with DC/DC Converter no need of any load side filter, here get constant DC.

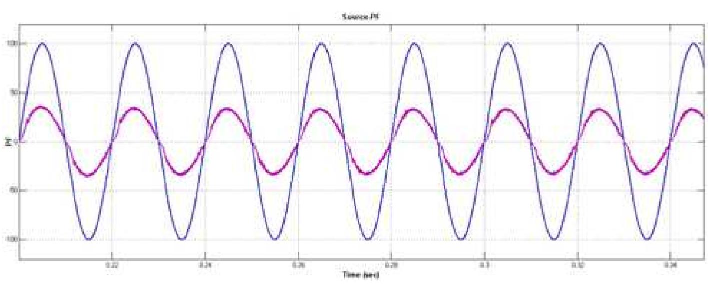


Figure 16: Source Power Factor of AC/DC Conversion with DC/DC Converter

Figure .16 Source Power Factor of AC/DC conversions with DC/DC converter, no need of load side filter to get constant DC output voltage as well, no distortions present in source side parameters then both source voltages & current will be in phase condition.

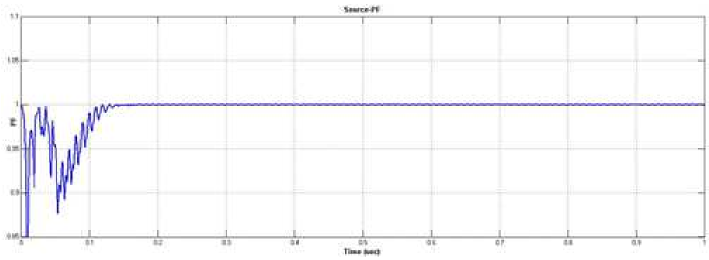


Figure 17: Source Power Factor of AC/DC conversion with DC/DC Converter

Figure 17 Source Power Factor of AC/DC conversion with DC/DC converter, power factor maintained at a constant to be corrected and as before condition drop to 0.6 lag condition and improved nearby unity condition.

Case 3: Proposed Open Loop & Closed Loop Control of 6/4 SRM Drive

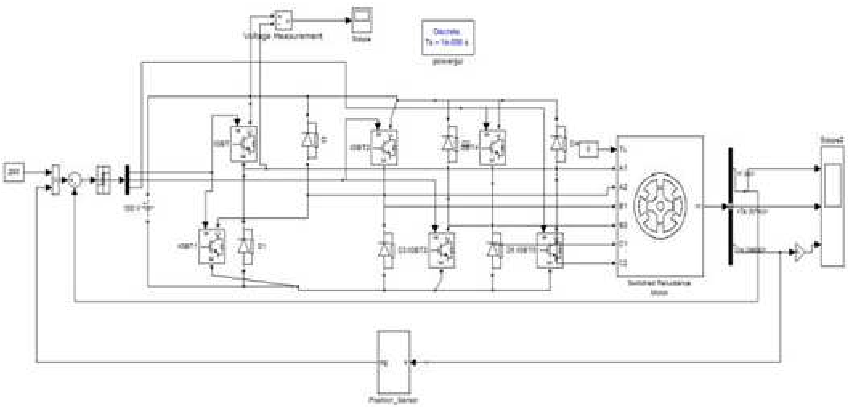


Figure 18: Matlab/Simulink Model of Proposed Open Loop Model Of 6/4 SRM Drive Configuration

Figure 18 Matlab/Simulink Model of Proposed Open Loop Model of 6/4 SRM Drive Configuration using Matlab/Simulink Software Package.

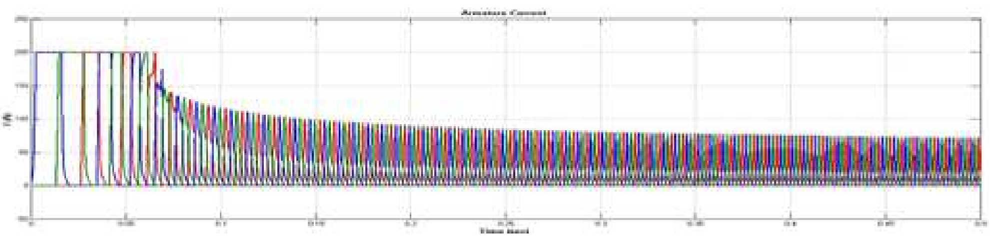


Figure 19

Current

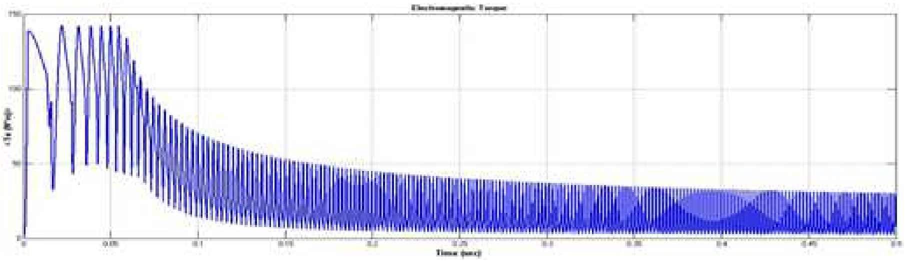


Figure 20

(b) Electromagnetic Torque

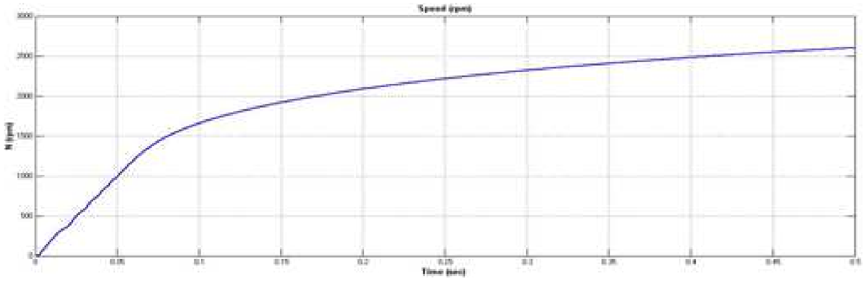


Figure 21

(c) Speed

Figure .21. Current, Electromagnetic Torque, Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration.

Figure 21 shows the Current, Electromagnetic Torque, and the Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration, due to its closed loop circuit one can achieve a faster response with low steady state error.

Case 3: The Proposed Closed Loop Control of SRM Drive Applications to Power Factor Correction Technique.

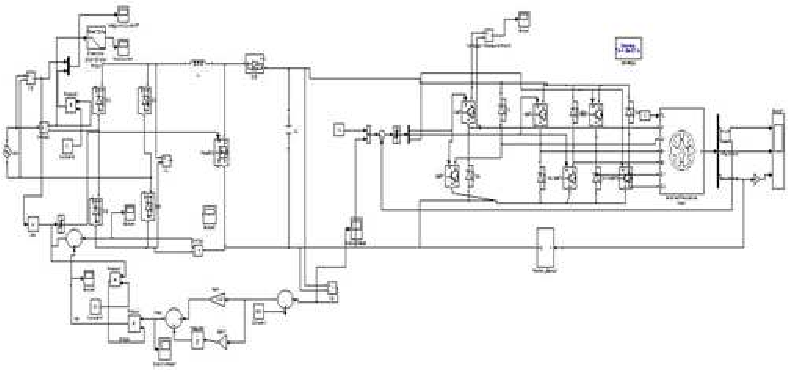


Figure 22: Matlab/Simulink Model of Proposed Closed Loop Model of 6/4 SRM Drive Configuration Applications to PFC

Figure 22 Matlab/Simulink Model of Proposed Closed Loop Model of 6/4 SRM Drive Configuration applications to PFC using Matlab/Simulink Software Package.

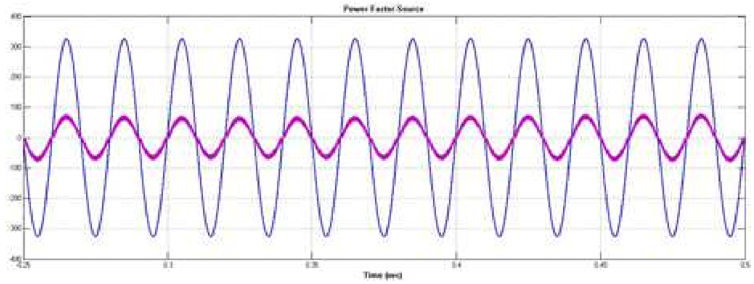
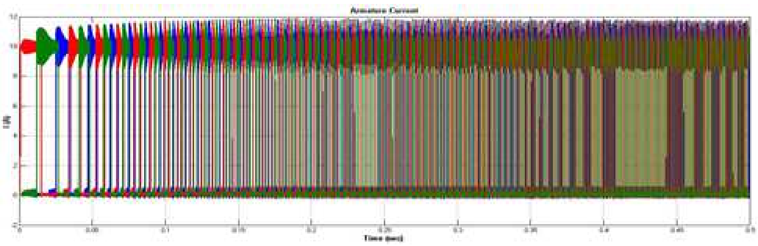
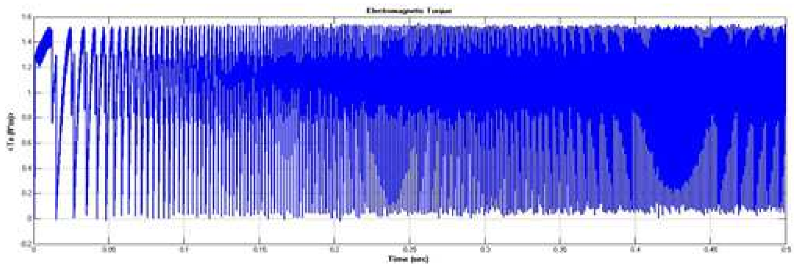


Figure 23: Source Power Factor of Proposed Scheme with DC/ DC Converter Fed Asymmetrical Converter with SRM Drive

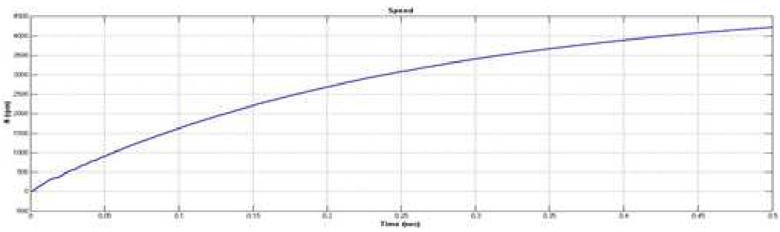
Figure 23 shows the Source Power Factor of Proposed Scheme with DC/DC converter fed asymmetrical converter with SRM drive, due to the proposed converter topology source current comes as pure sinusoidal with constant DC output voltage.



(a) Armature Current



(b) Electromagnetic Torque



(c) Speed

Figure 24: Current, Electromagnetic Torque, Speed of Proposed Closed Loop Model of 6/4 SRM Drive Configuration with PFC

Figure 24 shows the Current, Electromagnetic Torque, and the Speed of Closed Loop Model of 6/4 SRM Drive Configuration with Power Factor Correction, due to closed loop circuit one can achieve a fast response with low steady state error and improve the PF at source side.

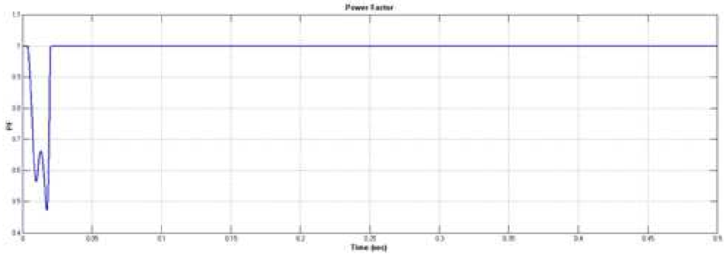


Figure 25: Source Power Factor of AC/DC Conversion with DC/DC Converter Fed SRM Drive

Figure 25 Source Power Factor of AC/DC conversion with DC/DC converter Fed SRM Drive, power factor (pf) is maintained at constant value and is improved nearer to unity.

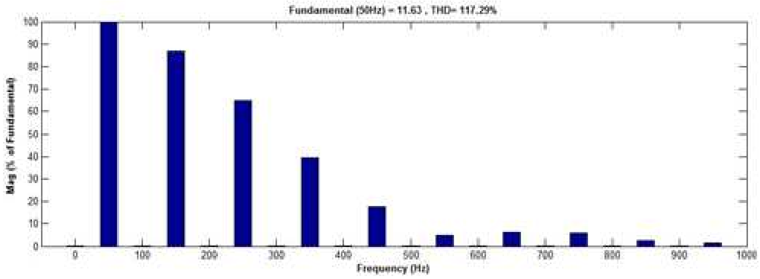


Figure 26: FFT Analysis of Source Current with DC Link Capacitor (Before Power Factor Correction)

Figure 26 shows the FFT Analysis of Current source with a Capacitor, and it exhibits 117.29% out of IEC standards.

As below Figure 27 shows the FFT Analysis of Source Current with proposed DC/DC converter fed SRM drive; get 1.59% within IEC standards.

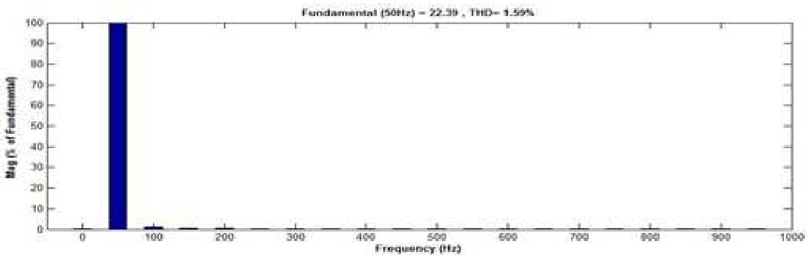


Figure 27: FFT Analysis of Source Current with Proposed DC/DC Converter Fed SRM Drive (after Power Factor Correction)

CONCLUSIONS

Switched Reluctance Motor (SRM) has become a competitive selection for many applications of electric machine drive systems recently due to its relative simple construction and its robustness. This paper highlights diode bridge rectifier (DBR) based converter is established to modify the input current of the drive, improving the power factor of SRM drive. Dc link's capacitors eliminating and as a result, creating capability of proposed DC/DC converter topology fed SRM is achieved by using asymmetrical converter. The input phase current frequency spectra clearly illustrate current THD improvement as within IEEE/IEC standards through power factor correction.Closed loop control using a PI controller with Kp and Ki values are presented in this paper for achieving fast response, low steady state error and low torque ripples. Closed loop controller for an SRM drive with power factor correction is implemented in Matlab/Simulink environment.

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